Surgical Technique of Pancreas Transplantation

Muhammad Arsalan Khan, Fowler R. Smith, and Jeffrey Rogers

Contents

Abstract

Pancreas transplantation has become accepted as the only definitive long-term treatment that reliably restores euglycemia by restoring endogenous insulin production and improving glucose counterregulation in patients with type 1 diabetes mellitus and in carefully selected patients with insulin-dependent type 2 diabetes mellitus. Despite five decades of experience and with more than 41,000 pancreas transplants performed worldwide through 2011, a multitude of variations exist in operative technique, reflecting the lack of consensus regarding the best method for implanting a pancreas allograft into a recipient. These differences in technique are primarily related to the method of pancreatic exocrine secretion drainage and the site of portal-venous drainage. The surgical technique of pancreas transplantation has evolved over time in response to technical complications and physiologic derangements associated with earlier

M. A. Khan · F. R. Smith · J. Rogers (✉)
Department of Surgery, Section of Abdominal Organ Transplantation, Wake Forest Baptist Medical Center, Winston-Salem, NC, USA
e-mail: mukhan@wakehealth.edu; frsmith@wakehealth.edu; jerogers@wakehealth.edu

A. P. Shah et al. (eds.), *Contemporary Pancreas and Small Bowel Transplantation*, Organ and Tissue Transplantation, https://doi.org/10.1007/978-3-319-05257-1_2001

methods of implantation. This chapter reviews the historical development of the pancreas transplant technique and elaborates on the rationale for the different variations currently practiced. Detailed descriptions of the most common technical approaches to implantation are provided.

Keywords
Pancreas transplantation · Technique · Systemic-enteric drainage · Systemic-bladder drainage · Portal-enteric drainage

Introduction

Pancreas transplantation is widely accepted as the only definitive long-term treatment that reliably restores euglycemia by restoring endogenous insulin production and improving glucose counterregulation in patients with type 1 diabetes mellitus and in carefully selected patients with insulin-dependent type 2 diabetes mellitus. The procedure renders patients insulin-free without the risk of severe hypoglycemia; improves quality of life and life expectancy; and can prevent, stabilize, and potentially reverse chronic complications of diabetes (Gruessner and Gruessner 2013). Pancreas transplantation is most commonly performed in conjunction with kidney transplantation in patients with advanced diabetic nephropathy (simultaneous kidney-pancreas transplant, SPK) but may also be performed in patients following successful deceased donor or living donor kidney transplantation (pancreas after kidney transplant, PAK). Much less commonly, pancreas transplantation is performed in nonuremic type 1 diabetics with glucose hyperlability, failure of exogenous insulin therapy, frequent episodes of life-threatening asymptomatic hypoglycemia, and well-defined secondary complications of diabetes that might benefit from improved glycemic control (pancreas transplant alone, PTA). PAK and PTA are collectively referred to as solitary pancreas transplants. In all cases, the benefits of pancreas transplantation come at the expense of major intra-abdominal surgery and the need for chronic immunosuppression. For recipients of primary deceased donor pancreas transplants, 1-year pancreas graft survival (insulin-free) rates are 85% in SPK, 80% in PAK, and 78% in PTA, with pancreas graft half-lives of nearly 14 years in SPK and 10 years in solitary pancreas transplant recipients (Gruessner 2011; Israni et al. 2012; Opelz 2013).

Despite five decades of experience and with more than 41,000 pancreas transplants performed worldwide through 2011, as documented in the International Pancreas Transplantation Registry (IPTR) 2013 report, a multitude of variations exist in operative technique, reflecting the paucity of evidence and the resultant dearth of consensus regarding the best method for implanting a pancreas allograft into a recipient. These differences in technique are primarily related to the method of pancreatic exocrine secretion drainage and the site of portal-venous drainage. Whether the pancreas is transplanted as a solitary organ or in combination with a kidney and whether the recipient has undergone previous kidney and/or pancreas transplantation also represent variations that may result in different operative approaches.

The surgical technique of pancreas transplantation has evolved over time in response to technical complications and physiologic derangements associated with earlier methods of implantation. Ongoing surgical innovation and creativity have aimed to optimize functional outcomes and recreate normal anatomy and physiology. Consequently, the most common techniques of pancreas transplantation that are currently employed are best understood in terms of how they came to be developed from a historical perspective. This chapter will review the historical development of pancreas transplantation technique and will discuss the rationale for the development and implementation of the various technical approaches. Detailed descriptions of the most common methods of implantation currently practiced will be provided.

History of Pancreas Transplantation and Evolution of Surgical Technique

On December 17, 1966, William Kelly and Richard Lillehei performed the first successful human pancreas transplant at the University of Minnesota (Kelly et al. 1967). A twenty-eight-year-old

uremic female with type I diabetes received a duct-ligated segmental pancreas graft along with a kidney from a deceased donor. She remained insulin-free for 6 days and this seminal event, in principle, proved the therapeutic power of pancreas transplantation. The ligated duct led to graft pancreatitis and a subsequent pancreatic fistula, and the patient died 2 months after the transplant from sepsis due to surgical complications.

Over the next 5 years, 25 pancreas transplants were performed worldwide at six institutions (Squifflet et al. 2008). Of these, 13 were performed by Lillehei at Minnesota, who changed his technique to transplantation of the whole pancreas along with duodenum, initially with external drainage of pancreatic exocrine secretions through a duodenal stoma and subsequently via duodenojejunostomy. The longest surviving pancreas graft from this series was functioning at 1 year after transplant and defined the criteria of successful pancreas transplantation at the time (Lillehei et al. 1970). The other institutions that contributed to the experience included University of Rio de Janeiro and University of Sao Paulo in Brazil, Buenos Aires Hospital in Argentina, University of Colorado and University of California, Irvine in the USA, and Guy's Hospital in UK. This experience highlights the recurring challenges of early pancreas transplantation related to management of exocrine secretions of transplanted pancreas, rejection leading to early graft failure, and postoperative mortality. Azathioprine-based immunosuppression also resulted in a higher susceptibility of donor duodenal segment to rejection compared to the pancreas or the kidney. This set the stage for next decade and a half, during which segmental pancreas grafts – body and tail, after removal of pancreatic head and attached duodenum – were used almost exclusively for transplantation.

The Era of Segmental Grafts and Contending with the Pancreatic Duct

To facilitate pancreatic exocrine drainage, Marvin Gliedman, at Montefiore Hospital and Medical Center in New York, performed a series of 11 pancreas transplants from late 1971 to the mid-1970s, in which the duct of a segmental pancreatic graft was anastomosed to the native ureter of the recipient after nephrectomy (Gliedman et al. 1973). The longest functioning graft with euglycemia in this series was 50 months. The procedure never achieved widespread acceptance because of problems with leakage from pancreatic cut surface and from the duct-to-ureter anastomosis as well as due to the need for native nephrectomy, which were criticized as negative aspects of this technique.

Another strategy to deal with the duct was developed based on experiments in dogs and pigs, in which the duct of the transplanted pancreas was left open to drain into the peritoneum. The animals tolerated this without any complications, presumably due to the lack of enzymatic activation. In 1976, Mick Bewick, at Guy's Hospital, London, performed the first open-drained pancreas transplant in a human recipient (Bewick 1976). This was followed by a series of 12 cases at University of Minnesota from 1978 to 1980. Three of these pancreas allografts were ultimately removed due to peritonitis or pancreatic ascites. The longest duration of insulin-independence recorded in this series was 18 years, curtailed only by the untimely death of the recipient from an accident.

At about the same time, an alternate technique of pancreatic duct occlusion was developed. Several different teams injected a variety of synthetic materials, such as neoprene, prolamine, and silicone, into the pancreatic duct of a segmental allograft to occlude the duct. Despite numerous complications, including leaks, fistulas and pancreatitis related to duct occlusion, the technique remained popular. Jean-Michel Dubernard, the original proponent of the technique, proposed wrapping the duct occluded pancreatic segment with omentum (omentoplasty) as a way to contain these problems (Dubernard et al. 1979; Dubernard et al. 1987).

A New Beginning: The Era of Cyclosporine, Whole Organ Grafts, and Bladder Drainage of Exocrine Secretions

In 1979, Roy Calne made a landmark contribution to the field of organ transplantation by

demonstrating the clinical utility of cyclosporine for immunosuppression (Calne 2004). Effective immunosuppression opened the door to a new era of transplantation in which graft survival increased dramatically. Simultaneous surgical innovations enabled pancreas transplantation to begin to approach its current level of efficacy. This was followed almost immediately by a worldwide collaboration of the scientific community, with the development of International Pancreas Transplant Registry (IPTR) at the University of Minnesota in 1980 and a series of workshops known as the Spitzingsee meeting in Austria, in 1981, where the pioneers of pancreas transplantation gathered together to review their experiences and brainstorm about potential strategies to improve outcome (Squifflet et al. 2008). Two influential recommendations through the discourse that ensued had a practice-changing effect on operative technique of pancreas implantation over the next 15 years. Hans Sollinger, of University of Wisconsin, proposed draining pancreatic exocrine secretions into bladder as an alternative to enteric drainage to obviate the complications of intestinal anastomotic leaks, abscess, peritonitis, and sepsis associated with enteric drainage. Additionally, there was a consensus that whole organ pancreas graft was a better option than segmental grafts, particularly in an era of more effective immunosuppression.

In 1987, the technique for bladder drainage of whole organ pancreas grafts via duodenocystostomy was described by Dai Nghiem and Robert Corry at the University of Iowa (Nghiem and Corry 1987). This technique was rapidly adopted by most transplant centers in the USA and Europe, and soon thereafter, up to 90% of pancreas transplants were being performed in this way. Bladder drainage could be performed by either anastomosing a duodenal segment to the bladder as originally described (Iowa technique) or by anastomosing a button of duodenum surrounding the pancreatic duct orifice to the bladder (Wisconsin technique). A comparison between bladder drained pancreas transplants with duodenal button versus duodenal segment showed that bladder leaks, pancreatitis, bleeding episodes, and surgically related infections were all decreased with the duodenal segment technique (D'Alessandro et al. 1989); consequently, bladder drainage with duodenal segment became the prevailing technique. Bladder drainage was advantageous because the consequences of anastomotic leak were far less severe than the morbidity associated with enteric leak and could often be managed nonoperatively with Foley catheter decompression of the bladder. Additionally, serial quantitative measurement of urinary amylase could be used to monitor for rejection. Since rejection of the exocrine pancreas precedes rejection of the endocrine pancreas (Gruessner and Gruessner), a decline in urinary amylase could raise concern for rejection and might prompt pancreas biopsy or empiric treatment. Pancreas and kidney rejection occur synchronously approximately 90% of the time in SPK, so the serum creatinine can be used as a surrogate marker for pancreas rejection and can serve as an indication for kidney biopsy or pancreas biopsy, if technically feasible (Gruessner and Gruessner). In solitary pancreas transplantation (PAK and PTA), the absence of a kidney transplant from the same donor makes monitoring for rejection more challenging. Biochemical markers such as serum amylase and lipase can be associated with pancreas rejection but lack sensitivity and specificity. In view of the historically higher incidence of rejection in solitary pancreas transplants compared to SPK transplants, bladder drainage was viewed as the preferred technique for solitary pancreas transplantation and is still favored by some surgeons for these cases. Unfortunately, bladder drainage is associated with a variety of metabolic and urologic complications, including metabolic acidosis due to bicarbonate loss in the urine, dehydration, recurrent urinary tract infections, cystitis, and reflux pancreatitis (Sollinger et al. 1993). These complications were associated with frequent hospital readmissions and the need for enteric conversion in as many as 25% of bladder drained pancreas transplants (Ploeg et al. 1994). Consequently, a shift towards enteric drainage occurred in the mid-1990s. Since 1995, the number of pancreas transplants performed with primary enteric drainage has increased significantly and currently accounts for 91% of SPK, 89% of PAK, and 85% of PTA cases (Gruessner). With contemporary immunosuppression, careful

donor and recipient selection, and surveillance pancreas biopsies in solitary pancreas transplantation, similar long-term pancreas graft survival can be achieved in SPK and solitary pancreas transplant recipients with enteric drainage (Rogers et al. 2014b; Stratta et al. 2014; Bartlett et al. 1996).

The Current Era

Over the last two decades there was prolific growth of pancreas transplantation worldwide, with improvements in graft survival and a decreased incidence of surgical and immunosuppression-related complications; however, in recent years the volume of pancreas transplants performed has begun to decline, presumably due to improvements in diabetes management. The vast majority of deceased donor pancreas transplants are performed as whole organ grafts with variable lengths of duodenum, whereas segmental grafts are rarely obtained from deceased donors but remain the only option for live donor pancreas transplantation (Gruessner et al. 1997; Sutherland et al. 2001). Currently, over 80% of enteric-drained pancreas transplants are performed with systemic venous drainage of the donor portal vein into either the iliac vein or vena cava (Gruessner). This technique is not physiologic because it bypasses the liver and results in systemic hyperinsulinemia. To make pancreas transplantation more physiologic, Osama Gaber and colleagues introduced the technique of portal-venous drainage via the recipient superior mesenteric vein (SMV) in combination with enteric drainage of exocrine secretions (portal-enteric technique) (Gaber et al. 1993). In theory, portal-venous drainage was thought to have potential clinical benefits because it avoids the systemic hyperinsulinemia that occurs with systemic-enteric drainage. Peripheral hyperinsulinemia is known to be associated with dyslipidemia, insulin resistance, and development of atherosclerosis; interestingly, the clinical impact of these adverse events following systemic-enteric drainage has been minimal (Stadler et al. 2010; Katz et al. 1994). It was also hypothesized that portal presentation of donor antigen to the liver after portal-venous pancreas transplantation could be immunologically advantageous and might lower the incidence of rejection compared to systemic venous drainage, and an uncontrolled, retrospective study initially suggested that this might be the case (Philosophe et al. 2001). However, subsequent studies, including a randomized controlled study comparing portal-venous and systemic-venous drainage, failed to show any difference in rejection between the two techniques (Martin et al. 2000; Petruzzo et al. 2000; Stratta et al. 2001). A number of subsequent studies have not shown any differences in metabolic control, specifically, no differences in lipid profile or glycemic control (Bagdade et al. 1996; Petruzzo et al. 2004; Petruzzo et al. 2006). Patient and graft survival also appear to be similar between portal-venous and systemic-venous drainage (Bazerbachi et al. 2012; Martin et al. 2000; Petruzzo et al. 2000; Lo et al. 2001; Stratta et al. 2001). From a technical standpoint, portal-enteric drainage maybe advantageous because it is primarily a mid-abdominal rather than a pelvic procedure, which may be beneficial in patients who have undergone previous kidney and/or pancreas transplants or other pelvic procedures (Rogers et al. 2014). Anastomosis of the donor portal vein to the SMV, which is superficially located in the mesenteric root, also tends to be easier than anastomosis to a deeper iliac vein, especially if the pelvis is narrow. Technical disadvantages of portal-enteric drainage are that the arterial anastomosis may be more difficult, a longer Y-graft is required, and the pancreas graft is often surrounded by bowel, making it more difficult to assess sonographically and more challenging to biopsy percutaneously (Rogers et al. 2014). Currently, portal-enteric drainage accounts for only 18% of SPK and PAK and 10% of PTA transplants with enteric drainage (Gruessner). Although virtually all pancreas transplants are currently performed using technical variations of systemic-enteric, portal-enteric, and systemic-bladder drainage, current thinking dictates that the most appropriate choice of technique is primarily determined by patient anatomy and surgeon experience and preference.

Current Surgical Techniques

Pancreas Anatomy and Bench Reconstruction

Pancreas anatomy and bench reconstruction are detailed in a separate chapter but are summarized herein. The head of the pancreas shares the vascular supply of duodenum, which lies at the interface of embryological foregut and midgut. The superior pancreaticoduodenal artery arises from the gastroduodenal artery (GDA) and represents the foregut arterial supply, whereas the inferior pancreaticoduodenal artery arises from the superior mesenteric artery (SMA) and represents the midgut arterial supply. The splenic artery (SA) courses along the body of pancreas and supplies the body and tail via the dorsal pancreatic artery and multiple segmental branches. Both of these arterial systems are connected through collateral circulation that traverses the head and body of the pancreas. Venous drainage is primarily through the splenic vein (SV) and the superior mesenteric vein (SMV) and via their confluence into the portal vein.

The whole organ vascularized pancreas graft includes an attached duodenal segment along with the entire pancreas. The duodenal segment includes the first, second, and a variable length of third part of duodenum, usually stapled at both the ends and imbricated with a sutured seromuscular layer. The arterial supply includes the donor's SA and SMA, which gives rise to the inferior pancreaticoduodenal artery. Although some surgeons routinely reconstruct GDA to preserve perfusion of the superior pancreaticoduodenal artery, the GDA stump is most commonly ligated, while SA and SMA are reconstructed into a single vessel using a bifurcated donor arterial graft. The type of arterial reconstruction required and the choice of arterial conduit depends primarily on whether systemic or portal-venous drainage is planned. Because the recipient iliac artery is the site of arterial anastomosis in nearly all pancreas transplants, if systemic-venous drainage is to be performed into contiguous iliac veins, a longer arterial conduit is not required. However, if portal-venous drainage is to be performed, graft placement higher along the recipient's SMV in most cases requires a longer arterial conduit that can reach the proximal right common iliac artery. The donor common iliac artery bifurcation into the internal and external iliac arteries is most commonly used for arterial reconstruction. The common carotid artery bifurcation into internal and external carotid arteries can also be used. In the absence of a bifurcated arterial graft from the donor, an end-to-side anastomosis of SA into the SMA can be performed and the distal end of the SMA is used for anastomosis to the recipient artery, although this results in a short common arterial trunk and a more difficult arterial anastomosis in the recipient. When the donor iliac artery is used as the interposition Y-graft, the best size match is usually achieved by anastomosing the external iliac artery to the SMA and the internal iliac artery to the SA. This works best when systemic venous drainage is to be performed since a long arterial conduit is not required. However, with portal-venous drainage, a long Y-graft is required and the best way to maximize arterial length is to anastomose the longer limb of the external iliac artery to the shorter SA and the shorter limb of the internal iliac artery to the longer SMA. On occasion, an extension graft (of distal external iliac artery or other donor arterial graft) may be anastomosed end-to-end to the common iliac artery conduit in order to further lengthen the arterial reconstruction. The donor portal vein is dissected circumferentially and is the outflow vein which is anastomosed to the iliac vein, vena cava, or SMV of the recipient. The SA and SV are doubly ligated at the tail of the pancreas, the short gastric vessels are ligated, and the spleen is removed. The stumps of the SMV and SMA in the root of the small bowel mesentery are typically stapled with a vascular stapler. Many surgeons prefer to reinforce this staple line with running nonabsorbable suture to prevent bleeding after reperfusion of the graft.

Intraoperative Preparation and Incision

Most pancreas transplants are performed through a midline laparotomy incision, in large measure, because this approach is associated with fewest wound complications and allows simultaneous

placement of a kidney allograft when required. Moreover, it preserves all options for vascular reconstruction and exocrine drainage. An additional advantage of intraperitoneal placement of the pancreas is that it allows internal absorption of peripancreatic collections through the peritoneal lymphatic circulation. Alternatively, a transverse abdominal incision can be used for intraperitoneal graft placement. Some surgeons prefer retroperitoneal placement of the pancreas into the iliac fossa via a J-shaped iliac incision. A potential advantage of pelvic retroperitoneal placement is that this location is easily approached for pancreas biopsy. In such cases, the peritoneum is accessed via a peritoneal window for enteric drainage of exocrine secretions and for intraperitoneal drainage of peripancreatic fluid collections.

After induction of general anesthesia, a central venous catheter and radial arterial line are placed for monitoring. A Foley catheter is placed and a nasogastric tube is inserted according to surgeon preference. Pancreas transplantation using enteric drainage without insertion of a nasogastric tube has been described and can be performed with good results (Barth et al. 2008). Typically a first-generation cephalosporin is used for surgical-site prophylaxis, with doses repeated every three hours intraoperatively and two additional doses administered at eight hour intervals postoperatively. Following an initial time-out and incision, a formal abdominal exploration is performed, and the nasogastric tube is properly positioned in the gastric antrum. A Bookwalter or other self-retaining retractor is used for exposure.

Systemic-Enteric and Systemic-Bladder Drainage

The pancreas is typically placed on the right side due to easier access to the iliac vein or vena cava for venous anastomosis. The right colon, cecum, and terminal ileum are mobilized medially along the peritoneal reflection to facilitate exposure of the iliac vessels in the right iliac fossa. The right common iliac artery is dissected circumferentially to the level of the aortic bifurcation. The external iliac artery is also mobilized circumferentially. Although the arterial dissection is intraperitoneal, ligation of large lymphatics is recommended. The native ureter and gonadal vein are retracted laterally and protected. The distal vena cava is exposed and the external iliac veins are mobilized circumferentially. Many surgeons prefer to ligate and divide the internal iliac vein in order to maximize anterior mobilization of the common and external iliac vein. This facilitates anastomosis of a short donor portal vein and also minimizes the likelihood of tension on the portal vein. The internal iliac vein is best divided between silk ties with each end suture ligated with polypropylene suture to prevent bleeding. The pancreas can be oriented either head down (Fig. 1) or head up (Fig. 2) for systemic-enteric drainage according to surgeon preference but only head down for systemic-bladder drainage. Most patients have iliac artery atherosclerosis and calcifications, the location and extent of which often dictate the site of arterial anastomosis. Consequently, the site of venous anastomosis is typically limited by the location of the arterial anastomosis. The common or external iliac arteries can be used for the arterial anastomosis. The venous anastomosis can be performed on the vena cava, the common iliac vein, or external iliac veins. When the pancreas

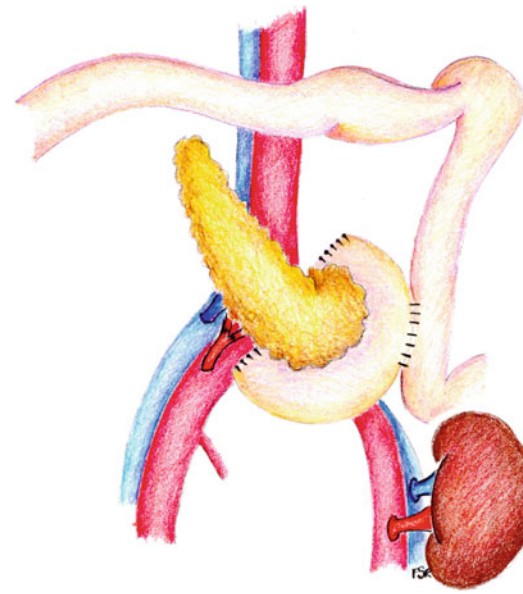

Fig. 1 Systemic-enteric drainage

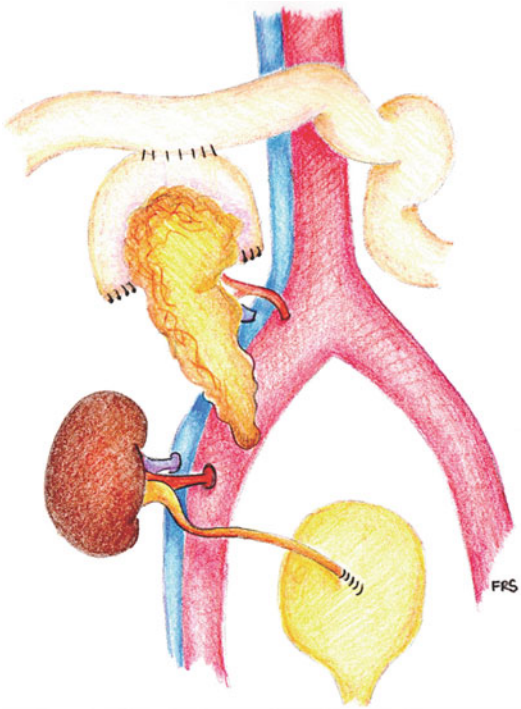

Fig. 2 Systemic-enteric drainage (pancreas head up) with ipsilateral kidney transplant

is positioned head down, it is important to not perform the arterial and venous anastomoses too distally on the external iliac vessels, especially in a narrow pelvis, as this can increase tension on both the portal vein and the transplant duodenum due to compression against the pelvic brim. The pancreas is placed in a laparotomy pad containing ice slush, and the Y-graft and portal vein are brought out through a hole cut in the laparotomy pad. The portal vein and Y-graft are carefully positioned to prevent scissoring when the vascular anastomoses are performed. Prior to clamping the vein, heparin 2000–3000 units (30–50 mg/kg) is administered intravenously in patients with a known thrombophilia and in recipients of a solitary pancreas transplant, since these patients may be more prone to graft vascular thrombosis. The vein is controlled with a large side-biting vascular clamp and a venotomy is created corresponding to the diameter of the donor portal vein. The venotomy is irrigated with heparinized saline solution. The portal vein may be extended with a segment of donor iliac vein if additional donor vein length is required; however, this is best avoided unless absolutely necessary since there is some evidence that a portal vein extension graft may increase the risk of venous thrombosis (Troppmann et al. 1995). The portal vein is anastomosed end-to-side to the recipient vein with 5–0 or 6–0 polypropylene suture using standard vascular technique. After completion of the venous anastomosis, a bulldog clamp is placed on the portal vein just above the anastomosis and the side-biting clamp is released, restoring iliac venous return from the right lower extremity. Any areas of venous anastomotic bleeding are repaired with polypropylene suture. The recipient iliac artery is then controlled with either a side-biting vascular clamp or with separate proximal and distal vascular clamps. An arteriotomy is made in the previously selected part of the iliac artery and is widened with a 4.8 mm or 5.2 mm arterial punch to facilitate anastomosis to the end of the Y-graft. The arteriotomy is irrigated with heparinized saline solution. The Y-graft is shortened as much as possible to prevent redundancy and kinking but must be left long enough to avoid tension. Prior to arterial anastomosis, the Y-graft is properly oriented with respect to the portal vein to prevent twisting or scissoring. The Y-graft is then anastomosed end-to-side the recipient artery. Mannitol 12.5 g is typically administered intravenously before reperfusion to minimize reperfusion pancreatitis. The laparotomy pad ice wrap is then removed and the pancreas is reperfused by first releasing the venous clamp followed by the arterial clamp. Hemostasis is achieved with gauze compression, electrocautery, and suture ligatures as needed. Common areas of bleeding after reperfusion are at the base of the portal vein and SMA, the small bowel mesentery staple or suture line, and at the distal SA and SV. After hemostasis is confirmed, attention is turned towards drainage of the exocrine secretions. When systemic-enteric drainage is performed, a segment of mid-jejunum is selected for duodenoenterostomy. Some surgeons emphasize the importance of not performing the bowel anastomosis too distally in the small bowel to avoid an increased risk of diarrhea; however, since the majority of water absorption occurs in the colon, this is more of a

theoretical concern. More importantly, the segment of recipient small bowel selected for the site of duodenoenterostomy should avoid tension on the donor duodenum and portal vein, especially when the pancreas is oriented head down. This is critical to minimize the likelihood of enteric leak and venous thrombosis, respectively. When the pancreas is oriented head up, a segment of proximal jejunum is usually selected for duodenoenterostomy. Prior to bowel anastomosis, the recipient bowel is controlled proximally and distally with bowel clamps to minimize enteric spillage. It is important to make sure that the pancreas is oriented properly with the mesentery facing upwards to avoid twisting of the portal vein and Y-graft. The authors prefer a 2-layer hand sewn, side-to-side anastomosis. The inner layer is performed with running, interlocking 3–0 polydioxanone for optimal hemostasis and the outer seromuscular layer is performed with 3–0 silk interrupted Lembert sutures. Alternatively, bowel anastomosis with a linear (Lam et al. 2006) or circular (Fridell et al. 2004a) stapler is favored by some surgeons. A Roux-en-Y diversion is preferred by some surgeons but is usually not necessary unless there are concerns about whether the transplant duodenum is adequately perfused. Bladder drainage of exocrine secretions can also be performed if there is any concern about the viability of the donor duodenum since the morbidity of a bladder leak is significantly less than an enteric leak. In cases of SPK, the kidney can be implanted on the left iliac vessels. Alternatively, the kidney can be implanted on the right external iliac artery and vein distal to the pancreas (Fridell et al. 2004b). This technique shortens the vascular dissection by avoiding the need to mobilize the sigmoid colon and expose the left iliac vessels. An additional benefit of ipsilateral kidney graft implantation is that it preserves the left iliac vessels for future transplantation. Ipsilateral kidney graft implantation should only be performed in cases of "head up" systemic-enteric pancreas transplantation or portal-enteric drainage (in which the pancreas and kidney are separated by the small bowel mesentery) to avoid the risk of having the duodenoenterostomy directly overlying the kidney graft vascular anastomoses.

If systemic-bladder drainage is performed (Fig. 3), the pancreas must be implanted on the iliac vessels such that the donor duodenum easily reaches the bladder without tension. Adequate bladder capacity is also a prerequisite. The bladder is distended with antibiotic irrigation solution via a three-way Foley catheter and the down drain is clamped. An area on the bladder dome is selected and the overlying peritoneal layer is opened with electrocautery. A posterior seromuscular layer of interrupted 3–0 silk suture is placed to approximate the bladder and transplant duodenum. These sutures must not be full thickness through the bladder to prevent leak and stone formation. The bladder is opened with the electrocautery and a corresponding opening is made in the transplant duodenum. The inner layer is performed with full thickness running 3–0 polydiaxonone suture and then the anterior seromuscular layer is completed with interrupted 3–0 silk Lembert sutures. The authors prefer to place a closed suction drain around the vascular anastomoses and under the bowel or bladder anastomosis, but this is optional. The pancreas is positioned in the right paracolic gutter and the right

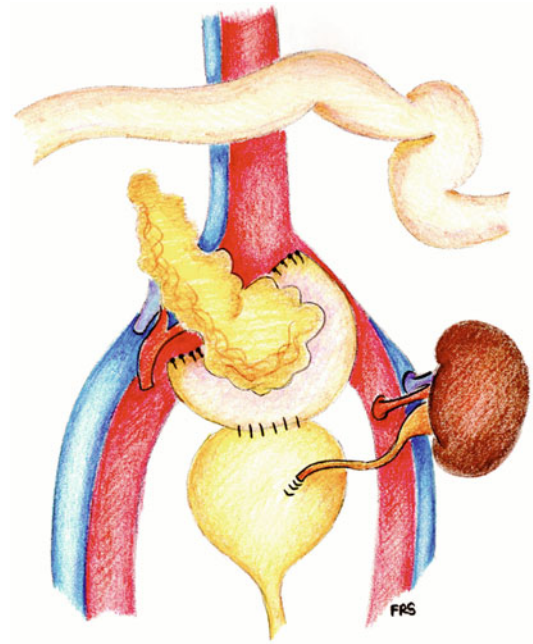

Fig. 3 Systemic-bladder drainage

colon is replaced over the pancreas. If an ipsilateral kidney transplant is performed, the right colon is tacked to the anterolateral abdominal wall overlying the kidney to prevent medial rotation and vascular torsion of the kidney.

Portal-Enteric Drainage

Abdominal exploration and circumferential exposure of the right common iliac artery to the level of the aortic bifurcation are performed as described above for systemic-enteric drainage. The external iliac artery and vein can also be exposed as described above if ipsilateral placement of a kidney graft is planned. The transverse mesocolon is retracted cephalad and the remaining viscera are retracted caudad to expose the root of the small bowel mesentery. The SMV can usually be identified in the mesentery between the duodenum and the palpable SMA. If the mesentery is thickened and the SMV is not visible, the SMA can be identified with a Doppler probe and the SMV can usually be found just to the right of the SMA. The mesentery is divided longitudinally over the SMV with the electrocautery and a 3–4 cm length of vein is exposed. Large side branches are encircled with vessel loops. If the vein diameter is >6 mm, then no further dissection is required. However, if the vein size is inadequate, a larger segment of vein can usually be exposed by carrying the mesenteric dissection higher. Portal-enteric drainage is not advisable if the SMV is <6 mm or if it is too deep or difficult to access, as is often the case in recipients with a BMI >30 kg/m^2 (Rogers et al. 2014a). It is common for the SMV to develop vasospasm in the process of dissection, so it is important to assess the SMV diameter before this occurs. Topical papaverine can be used to alleviate vasospasm of the SMV. Portal-enteric drainage is also contraindicated if the Y-graft is not long enough to traverse the small bowel mesentery and easily reach a segment of noncalcified iliac artery that is suitable for arterial anastomoses. In such cases, portal-enteric drainage is abandoned and the pancreas is typically implanted with systemic-enteric drainage. Circumferential dissection of the SMV is not required as long as the SMV can be safely controlled with a small side-biting clamp. Once the SMV dissection is completed and a landing zone on the iliac artery suitable for vascular anastomosis is identified, a small window is created in an avascular area of the distal ileal mesentery just above the iliac artery for passage of the Y-graft. Care must be taken not to injure vessels, bowel, or native duodenum when creating this window. Alternatively, a large mesenteric window can be created in the ileal mesentery allowing completion of both arterial and venous anastomoses anterior to the mesentery. This large mesenteric window must be partially closed after revascularization to prevent internal herniation of bowel. Yet another approach is to anastomose a segment of donor iliac or carotid artery, if available, to the recipient proximal common iliac artery prior to implantation of the pancreas. This jump graft is tunneled retrograde through the window in the ileal mesentery so that it is visible on the anterior side of the mesentery and available for end-to-end anastomosis to the Y-graft. The pancreas is placed in a laparotomy pad containing ice slush. The Y-graft is marked anteriorly to maintain orientation when it is passed through an opening cut in the laparotomy pad and when it traverses the mesenteric window. The pancreas is position head up with the mesenteric root anterior. If indicated, heparin is administered intravenously as described above. The SMV is controlled with a small side-biting vascular clamp, and a venotomy corresponding to the diameter of the donor portal vein is created. The venotomy is irrigated with heparinized saline solution. The portal vein is anastomosed end-to-side to the recipient vein with 6–0 polypropylene suture using standard vascular technique. Using a small needle (BV-1) is advisable to minimize tearing of the SMV, which can be quite thin walled. After completion of the venous anastomosis, a bulldog clamp is placed on the portal vein just above the anastomosis and the side-biting clamp is released, restoring portal venous return from the small bowel and testing the venous suture line for hemostasis. The Y-graft is then passed through the mesenteric window so that it emerges above the previously exposed common iliac artery,

taking care to ensure that the arterial conduit is not twisted as it traverses the mesentery. The Y-graft is trimmed to an appropriate length, and the distal end is beveled to enlarge the size of the anastomosis. With retractors pulling cephalad on the distal ileum and cecum, the end of the Y-graft should just reach the site of arterial anastomosis without tension since some additional redundancy is achieved when the retractors are released. If too much slack is left in the Y-graft prior to arterial anastomosis, there may be enough redundancy to result in kinking of the arterial conduit after the retractors are released. The proximal common iliac artery is controlled with a large side-biting vascular clamp or with individual clamps on the proximal common iliac, external iliac, and internal iliac arteries. An arteriotomy is made and widened with a 4.8 mm or 5.2 mm aortic punch, and the Y-graft is anastomosed end-to-side to the iliac artery with 5–0 polypropylene running suture using standard vascular technique. Before reperfusion, mannitol 12.5 g is administered intravenously. A vascular clamp is then placed on the Y-graft proximal to the arterial anastomosis and the iliac artery clamps are released. This allows the arterial anastomosis to be tested before reperfusing the pancreas and for any necessary additional sutures to be placed at the arterial anastomosis to secure hemostasis. This also allows the surgeon to focus all attention on achieving hemostasis of the pancreas graft above the mesentery after reperfusion. The laparotomy pad ice wrap is then removed and the pancreas is reperfused by first removing the bulldog clamp from the portal vein followed by removing the clamp from the Y-graft. Hemostasis is then achieved as described for systemic-enteric drainage. The authors prefer to perform a duodenoenterostomy between the posterior aspect of the distal transplant duodenum and a segment of ileum approximately 5 ft from the ileocecal valve. This allows for dependent drainage from the atonic transplant duodenum into the recipient bowel (Fig. 4). The bowel anastomosis is performed as a side-to-side two-layer hand sewn anastomosis as described for systemic-enteric drainage, although the enteric anastomosis can also be performed with staplers according to surgeon preference. Some surgeons prefer to anastomose the transplant duodenum into a defunctionalized Roux-en-Y limb with or without a venting jejunostomy (Zibari et al. 2000), into an omega loop (Losanoff et al. 2006), or directly into the native duodenum or stomach (Shokouh-Amiri and Zibari 2011; De Roover et al. 2007; Hummel et al. 2008). The

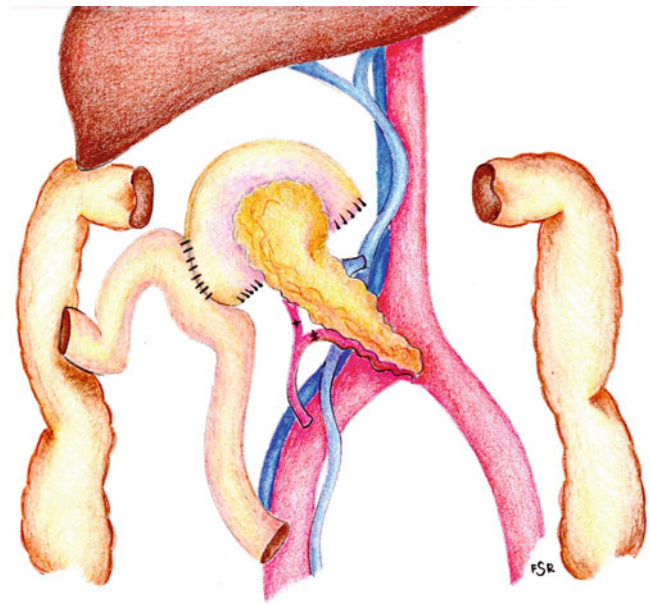

Fig. 4 Portal-enteric drainage

latter three options are uncommon and have been reported in some recent small series; these procedures have the advantage of allowing easy access for endoscopic surveillance and biopsy of the transplant duodenum and pancreatic head but may be associated with greater morbidity if there is an anastomotic leak. Although it involves creating an additional enteric anastomosis, a diverting Roux-en-Y limb is usually the safest procedure if there is any question about whether the transplant duodenum is adequately perfused.

A newer variation of portal-enteric drainage, described by Ugo Boggi, involves retroperitoneal placement of the pancreas with vascular anastomosis to the lateral aspect of the SMV and the proximal common iliac artery (Boggi et al. 2005). A Roux-en-Y limb is brought through a window in the right colon mesentery for side-to-side enteric anastomosis. Alternatively, a side-to-side duodenoduodenostomy can be performed to the native duodenum, which eliminates the need for a Roux limb or mesenteric window. Regardless of technique, it is important to ensure that the efferent limb of small bowel beyond the duodenoenterosomy is not kinked, since this can result in bowel obstruction and duodenal blowout. Prior to abdominal closure, the authors prefer to place a closed suction drain around the pancreatic vessels and beneath the bowel anastomosis, although this is optional.

Conclusion

Since the first pancreas transplant was performed in 1966, the technical evolution and ongoing refinements of the procedure, combined with improvements in organ recovery and preservation, major advances in immunosuppression and anti-infective prophylaxis, and increased experience with donor and recipient section, have resulted in excellent long-term patient and graft survival. Although a variety of implantation techniques are currently practiced, there are advantages and disadvantages associated with each approach. Familiarity and experience with the various surgical options currently available provide pancreas transplant surgeons with the flexibility to choose the best operative approach for a specific set of donor and recipient characteristics, thereby maximizing the likelihood of a technically and functionally successful pancreas transplant.

Cross-References

▶ Donor Evaluation and Procurement
▶ Surgical Complications of Pancreas Transplant

References

Bagdade JD, Ritter MC et al (1996) Differing effects of pancreas-kidney transplantation with systemic versus portal venous drainage on cholesteryl ester transfer in IDDM subjects. Diabetes Care 19(10):1108–1112

Barth RN, Becker YT et al (2008) Nasogastric decompression is not necessary after simultaneous pancreas-kidney transplantation. Ann Surg 247(2):350–356

Bartlett ST, Schweitzer EJ et al (1996) Equivalent success of simultaneous pancreas kidney and solitary pancreas transplantation. A prospective trial of tacrolimus immunosuppression with percutaneous biopsy. Ann Surg 224(4):440–449 (Discussion 449–452)

Bazerbachi F, Selzner M et al (2012) Portal venous versus systemic venous drainage of pancreas grafts: impact on long-term results. Am J Transplant 12(1):226–232

Bewick M (1976) Proceedings: clinical pancreatic allotransplantation: a review of world results. Ann R Coll Surg Engl 58(4):326

Boggi U, Vistoli F et al (2005) A technique for retroperitoneal pancreas transplantation with portal-enteric drainage. Transplantation 79(9):1137–1142

Calne R (2004) Cyclosporine as a milestone in immunosuppression. Transplant Proc 36(2 Suppl):13S–15S

D'Alessandro AM, Sollinger HW et al (1989) Comparison between duodenal button and duodenal segment in pancreas transplantation. Transplantation 47(1):120–122

De Roover A, Coimbra C et al (2007) Pancreas graft drainage in recipient duodenum: preliminary experience. Transplantation 84(6):795–797

Dubernard JM, Sanseverino R et al (1987) Comparison of segmental pancreatic transplantation with duct obstruction and pancreaticoduodenal transplantation with enteric diversion. Transplant Proc 19(5):3572–3574

Dubernard JM, Traeger J et al (1979) Long-term effect of neoprene injection in the canine pancreatic duct. Transplant Proc 11(2):1498–1499

Fridell JA, Milgrom ML et al (2004a) Use of the end-to-end anastomotic circular stapler for creation of the duodenoenterostomy for enteric drainage of the pancreas allograft [corrected]. J Am Coll Surg 198(3):495–497

Fridell JA, Shah A et al (2004b) Ipsilateral placement of simultaneous pancreas and kidney allografts. Transplantation 78(7):1074–1076

Gaber AO, Shokouh-Amiri H et al (1993) A technique for portal pancreatic transplantation with enteric drainage. Surg Gynecol Obstet 177(4):417–419

Gliedman ML, Gold M et al (1973) Pancreatic duct to ureter anastomosis for exocrine drainage in pancreatic transplantation. Am J Surg 125(2):245–252

Gruessner AC (2011) 2011 update on pancreas transplantation: comprehensive trend analysis of 25,000 cases followed up over the course of twenty-four years at the International Pancreas Transplant Registry (IPTR). Rev Diabet Stud 8(1):6–16

Gruessner RW, Gruessner AC (2013) The current state of pancreas transplantation. Nat Rev Endocrinol 9(9): 555–562

Gruessner RW, Kendall DM et al (1997) Simultaneous pancreas-kidney transplantation from live donors. Ann Surg 226(4):471–480 (discussion 480–482)

Hummel R, Langer M et al (2008) Exocrine drainage into the duodenum: a novel technique for pancreas transplantation. Transpl Int 21(2):178–181

Israni AK, Skeans MA et al (2012) OPTN/SRTR, Annual data report: pancreas. Am J Transplant 14(Suppl 1):45–68

Katz HH, Nguyen TT et al (1994) Effects of systemic delivery of insulin on plasma lipids and lipoprotein concentrations in pancreas transplant recipients. Mayo Clin Proc 69(3):231–236

Kelly WD, Lillehei RC et al (1967) Allotransplantation of the pancreas and duodenum along with the kidney in diabetic nephropathy. Surgery 61(6):827–837

Lam VW, Wong K et al (2006) The linear cutting stapler for enteric anastomosis: a new technique in pancreas transplantation. Transpl Int 19(11):915–918

Lillehei RC, Simmons RL et al (1970) Pancreaticoduodenal allotransplantation: experimental and clinical experience. Ann Surg 172(3):405–436

Lo A, Stratta RJ et al (2001) Long-term outcomes in simultaneous kidney-pancreas transplant recipients with portal-enteric versus systemic-bladder drainage. Am J Kidney Dis 38(1):132–143

Losanoff JE, Harland RC et al (2006) Omega jejunoduodenal anastomosis for pancreas transplant. J Am Coll Surg 202(6):1021–1024

Martin X, Dawahra M et al (2000) Kidney-pancreas transplantation: our experience with systemic and portal drainage of pancreatic graft. Transplant Proc 32(2):421–422

Nghiem DD, Corry RJ (1987) Technique of simultaneous renal pancreatoduodenal transplantation with urinary drainage of pancreatic secretion. Am J Surg 153(4): 405–406

Opelz G (2013) President's address. The transplantation society – Berlin 2012. Transplantation 95(1):4–7

Petruzzo P, Badet L et al (2006) Metabolic consequences of pancreatic systemic or portal venous drainage in simultaneous pancreas-kidney transplant recipients. Diabet Med 23(6):654–659

Petruzzo P, Konan PG et al (2000) A randomized trial in simultaneous pancreas-kidney transplantation: portal versus systemic venous drainage of the pancreas allograft. Transplant Proc 32(8):2776–2777

Petruzzo P, Laville M et al (2004) Effect of venous drainage site on insulin action after simultaneous pancreas-kidney transplantation. Transplantation 77(12): 1875–1879

Philosophe B, Farney AC et al (2001) Superiority of portal venous drainage over systemic venous drainage in pancreas transplantation: a retrospective study. Ann Surg 234(5):689–696

Ploeg RJ, Eckhoff DE et al (1994) Urological complications and enteric conversion after pancreas transplantation with bladder drainage. Transplant Proc 26(2): 458–459

Rogers J, Farney AC et al (2014a) Pancreas transplantation with portal venous drainage with an emphasis on technical aspects. Clin Transplant 28(1):16–26

Rogers J, Farney AC et al (2014b) Pancreas transplantation: The Wake Forest experience in the new millennium. World J Diabetes 5(6):951–961

Shokouh-Amiri H, Zibari GB (2011) Portal-endocrine and gastric-exocrine drainage technique in pancreatic transplantation. Int J Organ Transplant Med 2(2): 76–84

Sollinger HW, Messing EM et al (1993) Urological complications in 210 consecutive simultaneous pancreas-kidney transplants with bladder drainage. Ann Surg 218(4):561–568 (Discussion 568–570)

Squifflet JP, Gruessner RW et al (2008) The history of pancreas transplantation: past, present and future. Acta Chir Belg 108(3):367–378

Stadler M, Anderwald C et al (2010) Chronic peripheral hyperinsulinemia in type 1 diabetic patients after successful combined pancreas-kidney transplantation does not affect ectopic lipid accumulation in skeletal muscle and liver. Diabetes 59(1):215–218

Stratta RJ, Farney AC et al (2014) Similar results with solitary pancreas transplantation compared with simultaneous pancreas-kidney transplantation in the new millennium. Transplant Proc 46(6):1924–1927

Stratta RJ, Shokouh-Amiri MH et al (2001) A prospective comparison of simultaneous kidney-pancreas transplantation with systemic-enteric versus portal-enteric drainage. Ann Surg 233(6):740–751

Sutherland DE, Gruessner RW et al (2001) Lessons learned from more than 1,000 pancreas transplants at a single institution. Ann Surg 233(4):463–501

Troppmann C, Benedetti E et al (1995) Impact of vascular reconstruction technique on posttransplant pancreas graft thrombosis incidence after simultaneous pancreas-kidney transplantation. Transplant Proc 27(1): 1331–1332

Zibari GB, Aultman DF et al (2000) Roux-en-Y venting jejunostomy in pancreatic transplantation: a novel approach to monitor rejection and prevent anastomotic leak. Clin Transplant 14(4 Pt 2):380–385